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THE REPORT TO CONGRESS

WASTE DISPOSAL PRACTICES AND THEIR EFFECTS ON GROUND WATER

EXECUTIVE SUMMARY

January 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Water Supply

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

THE ADMINISTRATOR

Dear Mr. President:

I am pleased to transmit the Report to Congress "Waste Disposal Practices and Their Effects on Ground Water" presenting the results of a survey and study carried out pursuant to Section 1442(a)(4) of Public Law 93-523, the Safe Drinking Water Act.

The Report is an evaluation of the impact of waste disposal practices upon present and future underground sources of drinking water. The Report also assesses the ability of Federal, State and local authorities to control such practices. The Report does not reflect the impact of the recently enacted Toxic Substances Control Act (P.L. 94-469) and the Resource Conservation and Recovery Act (P.L. 94-580) which will provide added protection of ground water as they are implemented.

The Report is transmitted in two volumes. One volume is an Executive Summary and the second is the Report itself. All the material presented in the Executive Summary is duplicated in the full Report so that it will stand alone as a complete document.

Sincerely yours,

Russell E. Train

Honorable Nelson A. Rockefeller
President of the Senate
Washington, D. C. 20510

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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Honorable Carl Bert Albert
Speaker of the House
Washington, D. C. 20515

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Ground water is a high quality, low cost, readily available source of drinking water.

- Half of the population of the United States is served by ground water.
- In many areas, ground water is the only high quality, economic source available.
- The use of ground water is increasing at a rate of 25 percent per decade.

Waste disposal practices have affected the safety and availability of ground water, but the overall usefulness has not been diminished on a national basis.

- Current data indicate that there are at least 17 million waste disposal facilities emplacing over 1,700 billion gal. (6.5 billion cu m) of contaminated liquid into the ground each year. Of these, 16.6 million are domestic septic tanks emplacing about 800 billion gal. (3 billion cu m) of effluent.
- Ground water has been contaminated on a local basis in all parts of the nation and on a regional basis in some heavily populated and industrialized areas, precluding the development of water wells. Serious local economic problems have occurred because of the loss of groundwater supplies.
- Degree of contamination ranges from a slight degradation of natural quality to the presence of toxic concentrations of such substances as heavy metals, organic compounds, and radioactive materials.
- More waste, some of which may be hazardous to health, will be going to the land because of increased regulation against, and the rising costs of, disposal of potential contaminants to the air, ocean, rivers, and lakes.
- Removing the source of contamination does not clean up the aquifer once contaminated. The contamination of an aquifer can rule out its usefulness as a drinking water source for decades and possibly centuries.

Almost every known instance of ground-water contamination has been discovered only after a drinking-water source has been affected.

- Few state or local agencies systematically collect data on contamination incidents, water supply wells affected, and drinking-water supplies condemned as unsafe.
- Effective monitoring of potential sources of ground-water

contamination is almost non-existent.

- Typical water-well monitoring programs traditionally have not been directed toward protecting public health because water analyses normally do not include complete coverage of such significant parameters as heavy metals, organic chemicals, and viruses.
- There are potentially millions of sources of contamination and isolated bodies of ground-water contamination nationwide.
- While detailed national inventories of all potential sources of ground-water contamination have not been carried out, EPA and some states have begun some inventories and assessments of some waste disposal sources.

Waste disposal practices of principal concern are those related to industrial and urban activities.

- For every waste-disposal facility documented as a source of contamination, there may be thousands more sited, designed, and operated in a similar manner.
- The opportunity for severe contamination of ground water is greatest from industrial waste-water impoundments and sites for land disposal of solid wastes.
- Septic tanks and cesspools discharge large volumes of effluent directly to the subsurface. In many cases, the degree of treatment is not adequate to protect ground-water supplies.
- Contamination resulting from the collection, treatment, and disposal of municipal waste water exists but the magnitude is unknown.
- Because there is a known potential for contamination from the land spreading of industrial and municipal sludges, there is concern about the expected increase in sludge generation over the next decade.
- There have been far fewer reports of contamination of potable ground-water supplies by the several hundred industrial and municipal wells injecting into saline aquifers than from thousands of shallow wells used to dispose of sewage, runoff, and irrigation return flow to aquifers containing potable water.

Other waste-disposal practices, whose distribution is dependent upon geology, climate, and topography, have also contaminated ground water.

- Contamination from oil and gas field activities is caused primarily by improperly plugged and abandoned wells and, to a lesser degree, poorly designed and constructed operating production and disposal wells.
- Although specific case histories of ground-water contami-

nation related to the disposal of mine wastes do exist, adequate documentation of the problem is unavailable.
- Ground-water contamination from the disposal of animal feedlot wastes is a relatively new environmental problem, and few cases of ground-water contamination have been reported.

Existing technology cannot guarantee that soil attenuation alone will be sufficient to prevent ground-water contamination from a waste disposal source.

- Proper site selection as well as proper operation and maintenance of facilities, is the principal technique available for minimizing ground-water contamination problems.
- Such technology as advanced treatment and physical containment play a major preventive role where economics dictate that sites be located in areas of critical ground-water use.
- Land disposal of wastes is not environmentally feasible in many areas and such alternatives as waste transport, resource recovery, ocean disposal, and surface-water or air discharge should be investigated and may be more environmentally acceptable.
- Federal demonstration grants and technical assistance are provided to assist the development of new technology and facilitate the application of existing technology.

Existing Federal and state programs address many of the sources of potential contamination, but they do not provide comprehensive protection of ground water.

- Existing Federal programs administered by EPA which address ground water are (1) the Federal Water Pollution Control Act Amendments of 1972; (2) the Safe Drinking Water Act of 1974; and to a lesser degree (3) the Solid Waste Disposal Act of 1965; and (4) the National Environmental Policy Act of 1969.
- The FWPCAA provide for a statewide and areawide waste treatment management planning function which may include identifying and controlling pollution from mine runoff, the disposal of residual waste, and the disposal of pollutants on land or in subsurface excavations.
- FWPCAA also include (1) a program to issue permits for point sources of water pollution, including some wells; (2) best practicable treatment standards for municipal sewage effluent disposal which must address ground-water protection; (3) guidelines for land spreading of municipal sludges; and (4) municipal waste treatment facilities planning for areas where septic systems pose poten-

pal sludges; and (4) municipal waste treatment facilities planning for areas where septic systems pose potential adverse ground-water impacts.

- FWPCAA do not address the discharge of contaminants to ground water from surface impoundments, land disposal of solid wastes, septic systems, or most wells.
- The SDWA provides for a Federal/state cooperative effort to prevent endangerment of underground drinking water sources from industrial and municipal waste disposal wells, oil-field brine disposal wells and secondary recovery wells, and engineering wells. At present, surface impoundments are not included in this program, but some types of impoundments may be included at a later time.
- SDWA also provides that EPA may review any commitment of Federal financial assistance in an area designated as having a sole source aquifer.
- SDWA cannot be used to regulate land disposal of solid wastes, land application of sludges and effluents, or septic systems except under the emergency powers provisions of the Act.
- The Solid Waste Disposal Act contains no specific reference to ground water, however, guidelines developed under the Act provide for ground-water protection from pollution activities and surface drainage. There are also site development guidelines which consider the impact on ground water. These guidelines are only mandatory for Federal agencies.
- The NEPA requires Federal agencies to prepare environmental impact statements on major actions. Ground-water protection is a significant need for writing an EIS.
- While site selection is an important parameter in preventing ground-water contamination, there are no direct Federal controls in this area. States are encouraged to develop site selection programs within the context of their land-use planning and control authorities.
- Most state laws give broad authority to protect all waters of the state, including ground water. Such language, plus deficiencies in budget and staffing, force state and local agencies to act on cases of contamination only after the fact.
- States are beginning to develop programs which encourage prevention of contamination from some waste disposal sources.
- Because clean-up of contaminated ground water is rarely economically or technically feasible, action by the states has been directed toward condemning the affected water supply.
- Legal action is seldom taken against a specific source of contamination because individuals, private organizations, and public agencies seldom have the resources required to prove a specific source as the source of contamination.

A national strategy of ground-water protection will require a better understanding of the environmental, legal, technical, and economic complexities of dealing with the resource.

- Better coordination of existing regulatory programs and a better understanding of the impact of all regulatory actions on ground water is necessary. Regulatory programs need to reflect the close relationship between land, ground water and surface water.
- Inventories of ground-water contamination cases have shown that other contaminant sources including spills, salt-water intrusion, and highway deicing, have a significant impact on ground water. Many of these sources are not included within the scope of Federal/state ground-water protection programs, but may be addressed on a case-by-case basis.
- The most effective means for protecting ground water is to control and monitor the potential source of contamination and not the aquifer or point of withdrawal.
- New potential sources of contamination should be evaluated on a case-by-case basis.
- Existing potential contamination sources should be reviewed in order to develop control strategies that are instituted in accordance with local priorities.
- Increasing Federal regulation of surface-water and air discharge and ocean disposal may result in land disposal practices (particularly of sludge) which could contaminate ground water.
- At the present time, there does not exist a comprehensive Federal program for sludge management. However, EPA is developing a comprehensive program to address this issue.

INTRODUCTION

On December 14, 1974, the Safe Drinking Water Act became law (PL 93-523). Under Sec. 1442(a)(4) of the Act, the Administrator of the U. S. Environmental Protection Agency (USEPA) was directed to conduct a survey of "(A) disposal of waste (including residential waste) which may endanger underground water which supplies, or can reasonably be expected to supply, any public water systems, and (B) means of control of such waste disposal." This Executive Summary describes the results of the investigation. The information contained in the summary is covered in more detail and referenced in the Report to Congress.

Waste disposal practices included in this study are those activities which result in the actual collection and disposal of liquid, semi-solid, and solid wastes. Such materials include: (1) industrial waste water that is contained in surface impoundments (lagoons, ponds, pits, and basins); (2) municipal and industrial solid refuse and sludge that are disposed of on land; (3) sewage wastes from homes and industries that are discharged to septic tanks and cesspools; (4) municipal sewage and storm-water runoff that are collected, treated, and discharged to the land; (5) municipal and industrial sludge that is land spread; (6) brine from petroleum exploration and development that is injected into the ground or stored in evaporation pits; (7) solid and liquid wastes from mining operations that are disposed of in tailing piles, lagoons, or discharged to land; (8) domestic, industrial, agricultural, and municipal waste water that is disposed of in wells; and (9) animal feedlot waste that is disposed of on land and in lagoons. The sources of potential contaminants and their various routes to the ground-water system are shown on Figures 1 and 2. Table 1 lists the waste disposal practices discussed in this report and their relative impact on the ground-water environment. Appendix A is an estimate of the numbers of facilities, volumes of waste, and leakage to ground water.

The first few sections of the Report to Congress describe the use and occurrence of the ground-water resource along with the mechanisms of contamination. These are followed by a discussion of each of the major waste disposal practices. In the next section of the report, there is a discussion of the importance of non-waste disposal practices as they affect ground-water quality. The final two sections define the present status of Federal legislation that applies to ground-water quality protection and the various regulatory alternatives and strategies available to state and local agencies.

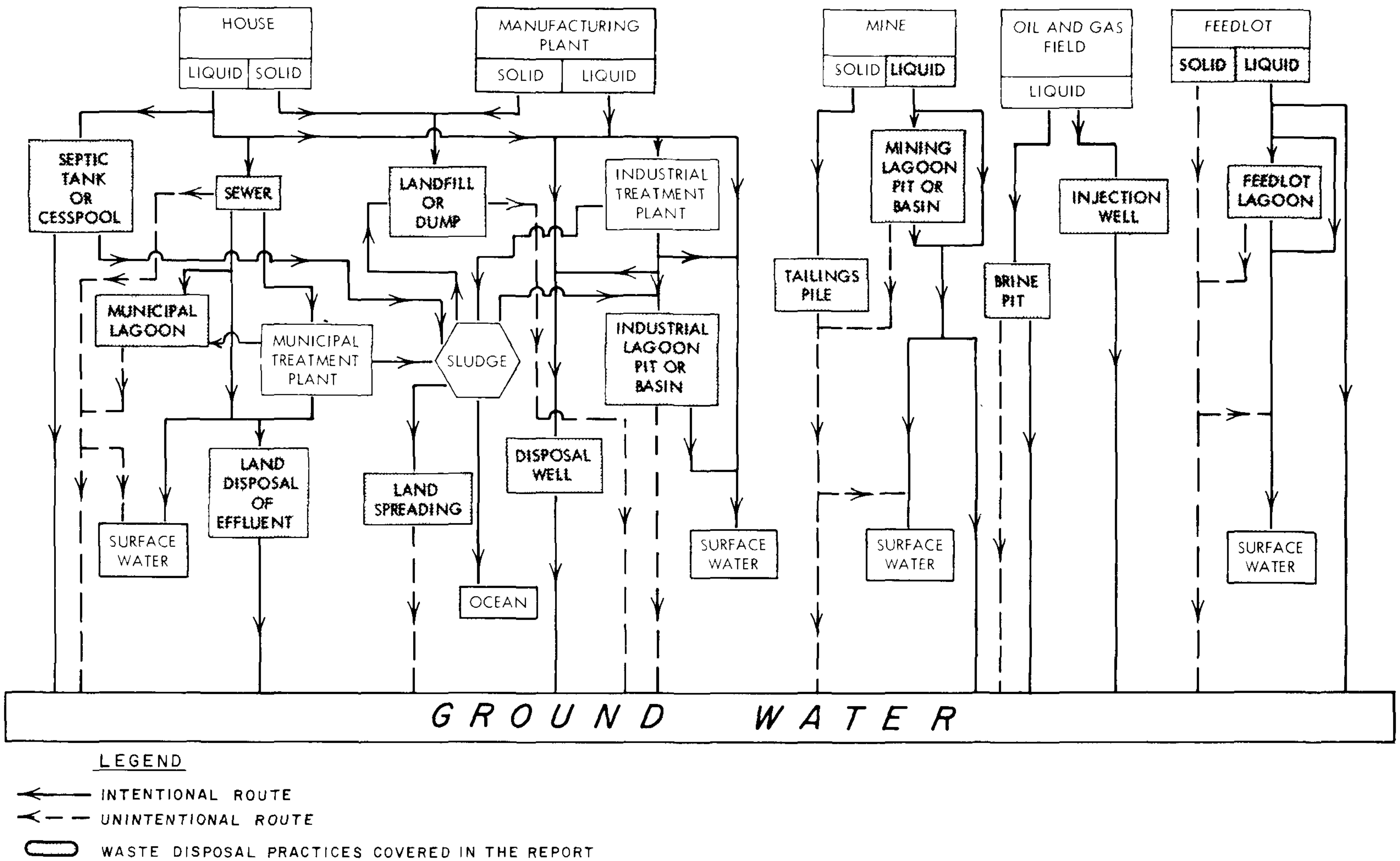


Figure 1. Waste disposal practices and the routes of contaminants from solid and liquid wastes.

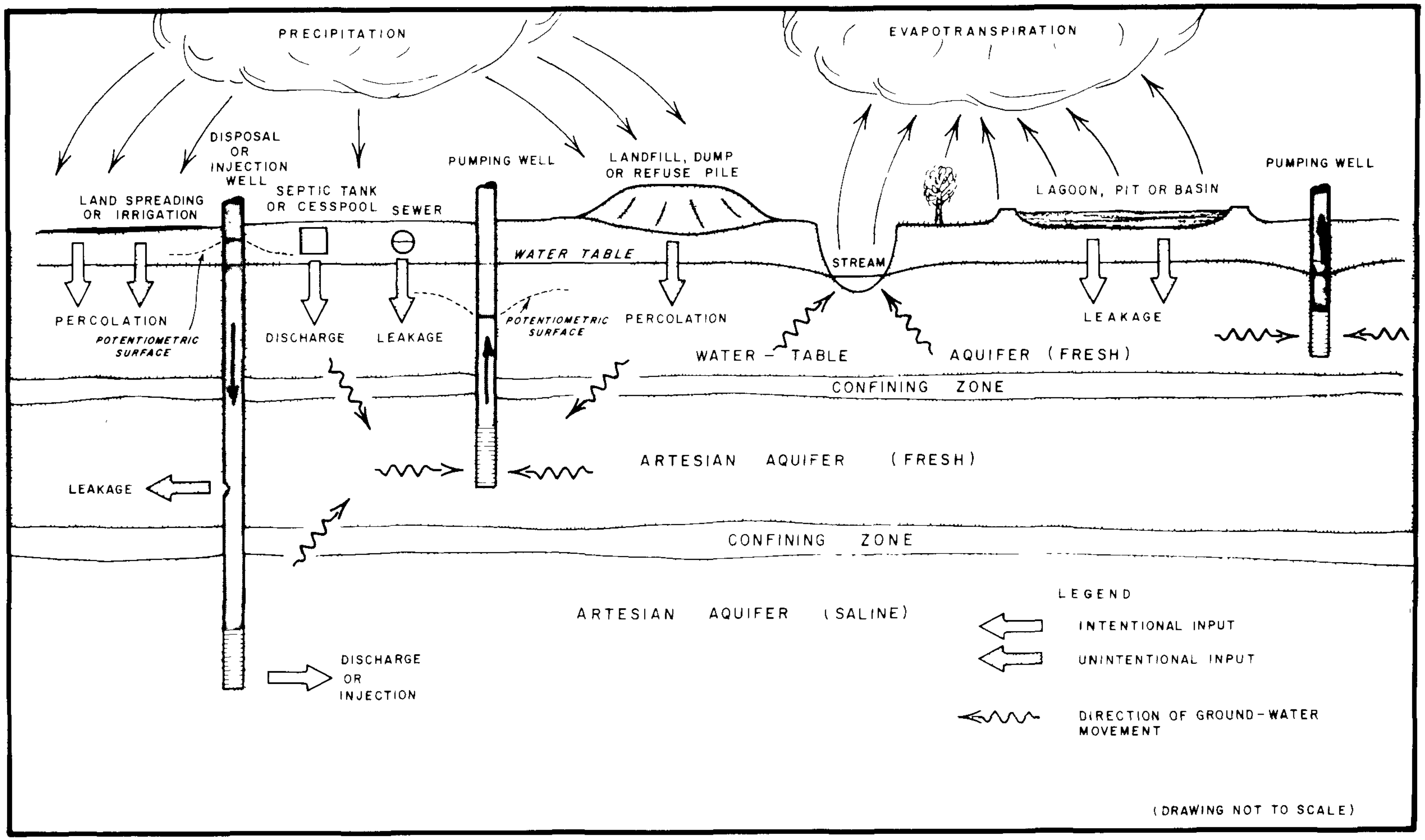


Figure 2. How waste disposal practices contaminate the ground-water system.

Table 1. WASTE DISPOSAL PRACTICES AND THEIR RELATIVE IMPACT.

Waste disposal practice	Frequency reported	Principal contaminants reported	Typical hazard to health	Typical size of affected area	Relative national importance	Future national importance	Principal EPA regions affected [b]
Industrial impoundments	I	Hm, P, A	I	y	I	I	II-V, VII, IX, X
Land disposal of solid waste		C, I, Hm, P					
Municipal	I		I	y	I	I	I-V, X
Industrial	III		I	y	I	I	– [c]
Septic tanks and cesspools		B, N, C					
Domestic	I		II	x	II	II	I-V
Industrial	III		I	y	II	II	– [c]
Municipal waste water		N, C, Hm					
Sewer systems	III		II	x	II	II	I-V, IX
Treatment lagoons	III		II	y	II	II	IV-VII, IX, X
Land spreading of sludge		N, Hm, P					
Municipal	III		II	y	III	I	I-V
Industrial	III		II	y	III	I	– [c]
Petroleum exploration and development		S, C, O					
Wells	II		III	x	II	II	III-IX
Pits	I		III	x	II	III	III-IX
Mine waste		Sa, I, Hm [a]					
Coal	III		III	y	II	I	III-V, VII, VIII
Other	III		II	y	II	II	IV-VI, VIII-X
Disposal and injection wells		Hm, A, T, M, N					
Agricultural, urban runoff, cooling water, and sewage	III		II	y	II	III	II, IV, IX, X
Industrial injection	III		I	y	III	III	III-IX
Animal feeding operations		N					
Cattle	III		III	z	III	III	VI-IX
Other	III		III	z	III	III	III-VIII

Table 1 (continued). WASTE DISPOSAL PRACTICES AND THEIR RELATIVE IMPACT.

EXPLANATION

I - high	A - Acids	N - Nitrate	x - small area, but can be regional due to high density of individual sources	a) dependent upon local mineralogy
II - moderate	B - Bacteria	O - Oil	y - can affect adjacent properties	b) for EPA regions, see figure attached
III - low	C - Chloride	F - Phenols	z - contained on one property	c) insufficient data for regional evaluation
	Hm - Heavy metals	S - Sodium		
	I - Iron	Sa - Sulfuric acid		
	M - MBAS	T - Temperature		

Frequency reported - based on the relative number of case histories described in published and unpublished sources.

Principal contaminants reported - based only on normally analyzed constituents. Unfortunately, for economic reasons, incomplete analyses are performed in most ground-water contamination cases. Therefore, the principal contaminants reported do not often include such hazardous substances as heavy metals, organic chemicals, or radioactive elements that may actually be present.

Typical hazard to health - based primarily on the nature of the contaminants with secondary consideration given to the typical volumes expected.

Relative national importance - based on the typical health hazard of the contaminants, the typical size of the area affected, and the distribution of the waste disposal practice across the U.S. A waste disposal practice may be a serious problem in certain areas; but if the number of such areas is relatively small, then the practice would not be given a high national rating. A very widespread practice which does not create serious problems even where sources of contamination are concentrated, would also be given a low rating with regard to national importance.

Future national importance - based on predicting what the relative national importance of each waste disposal practice will be in approximately ten years. The ratings take into account past and present technological trends in the treatment and disposal of wastes and evaluations of the impact of new and proposed regulations.

Principal regions affected - regions listed are the Environmental Protection Agency's Regions I through X as shown on the attached figure. Designations are based on present relative impact, taking into account the degree to which the waste disposal practice is carried out in the various regions and factors of geology and hydrology, where pertinent.

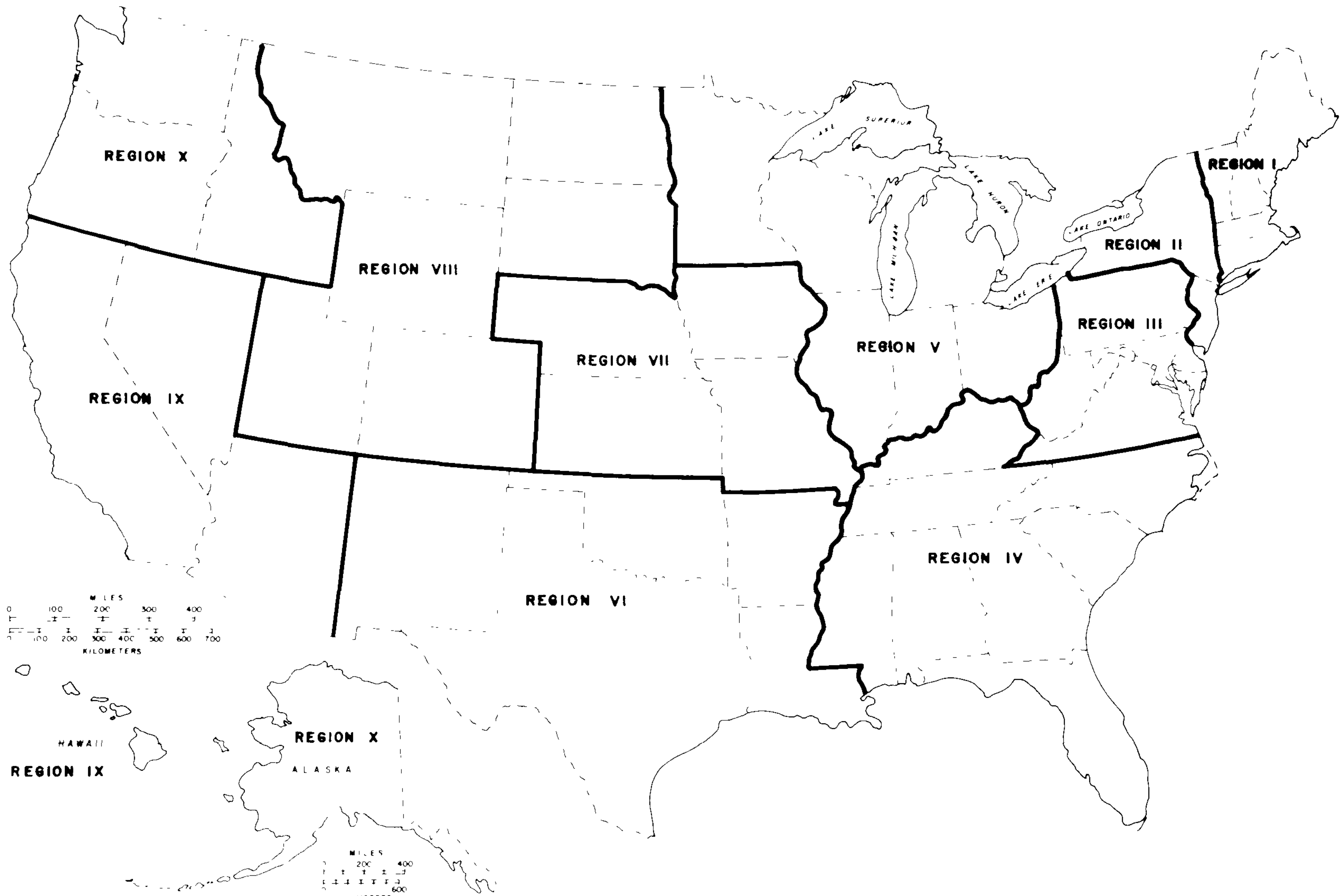


Table 1 (continued). U.S. Environmental Frotection Agency Regions.

Estimating the economic impact of technological or institutional controls was not one of the objectives of this survey.

The report is based on an evaluation and analysis of available data, a major portion of which has not been published. About 40 technicians in the ground-water and pollution-control fields contributed directly to this effort. Many more were contacted and provided the researchers with essential information. In addition, a working group consisting of representatives of various offices of EPA, plus personnel of state environmental agencies, periodically reviewed the report and contributed significantly to its content.

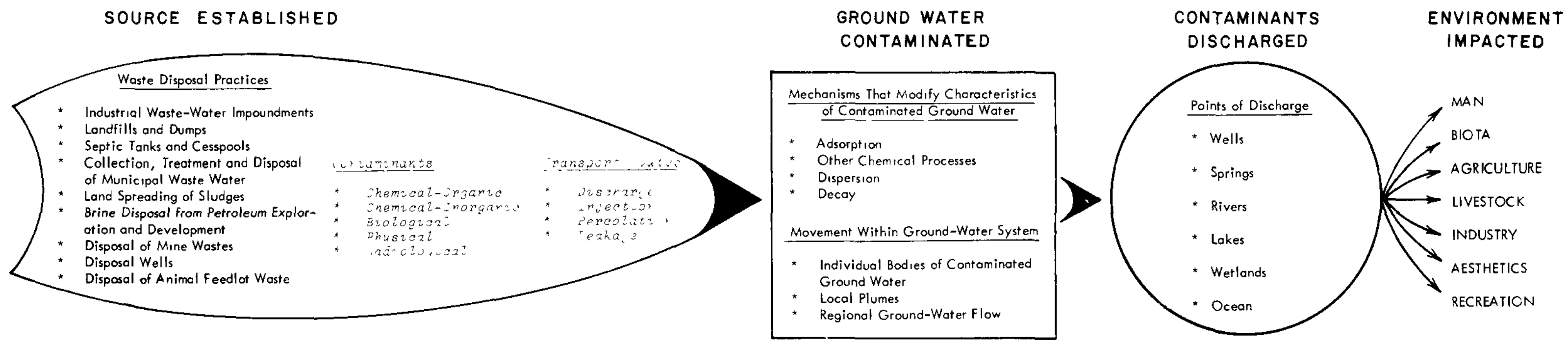
Ground-water contamination is the degradation of the natural quality of ground water as a result of man's activities. The term "contaminant" is defined in the Safe Drinking Water Act as "any physical, chemical, biological or radiological substance or matter in water." In this report, only those contaminants which result from waste disposal activities are considered in detail.

In order to appreciate the magnitude and severity of ground-water contamination, the hydrologic system itself, mechanisms of ground-water contamination, and environmental hazards must be understood. Figure 3 illustrates these concepts.

The contamination process begins with sources of contaminants; the waste disposal practices. The type of contaminant, of course, depends on the source and can range from hazardous organic chemicals in landfill leachates to high concentrations of salt in oil-field brines. Either deliberately (septic tanks) or unintentionally (industrial waste-water impoundments), contaminants can leak, percolate, be discharged to, or injected into water-supply aquifers.

As the contaminant travels through the soil and into the ground-water system, it can be modified by various attenuation processes. These processes are very complex and not all are completely effective. In fact, once in an aquifer, certain toxic substances, such as some heavy metals, are highly mobile. Attenuation in an aquifer is extremely slow as is the movement of ground water (typically less than 2 ft/day or 0.6 m/day). Therefore, contaminants within the ground-water system do not mix readily with native water and move as: (1) individual bodies or slugs (e.g., caused by intermittent filling of and seepage from waste-water impoundments); (2) local plumes (e.g., caused by continual flow of leachate from beneath a landfill toward a pumping well); and (3) masses of degraded water (e.g., caused by a large number of septic tanks discharging nitrate-enriched water which travels with

THE SYSTEM



METHODOLOGIES

	SOURCE	GROUND WATER SYSTEM	DISCHARGE	ENVIRONMENT
PREVENTION	Effective in Protecting the Resource * Control design, construction, and siting to prevent or minimize problems	Can Protect Ground-Water User Only * Regulate pumpage or diversion of ground water to control movement of contaminants in aquifer	Too Late * Treat, limit use of, or condemn water source, food supply, or recreational activity	
MONITORING	Early Warning * Only alternative available to monitor individual bodies and local plumes of contaminated ground water and to determine success of prevention techniques	*Intermediate Warning* * Useful for problems that have become regional and to monitor trends	Last Warning * Required as a safety measure and to monitor trends	Too Late
ABATEMENT	Long Term Benefits Only * Eliminating source prevents worsening of problem but does not clean up aquifer	Too Late * Clean-up of most aquifers is not technically or economically feasible		

Figure 3. The hydrologic system controlling ground-water contamination and its constraints on methodologies for prevention, monitoring, and abatement.

the regional ground-water flow pattern).

Although ground water travels through an aquifer slowly, it is in constant motion and must eventually discharge to the surface because all aquifer systems are being recharged to some degree. In humid areas, discharge of contaminants is relatively quick for shallow water-table aquifers and slow for deep artesian aquifers. In arid regions, recharge and discharge are so slow that some aquifers can actually be considered sinks similar to the ocean. Points of discharge include wells and springs used for water supply, and surface-water bodies such as rivers and lakes. In fact, the base flow of most streams is supported by ground-water discharge, and the quality of the surface water during low flow periods is dependent upon ground-water quality. The usefulness to man and his environment of both surface water and ground water is severely limited if ground-water quality is degraded.

The way the ground-water system works controls the methodologies available to prevent, monitor, and abate instances of contamination. Prevention must be directed toward the source, where proper design, construction and siting can help protect the resource or at least minimize problems. If the aquifer becomes contaminated, then the resource has already been degraded, and efforts must be shifted toward preventing the ground-water user from being damaged. Controls involve such actions as regulating pumpage patterns in order to contain or isolate the contaminant. When the contaminant reaches the point of discharge, it is too late except for such expensive alternatives as treatment or condemnation of a water supply.

Again, in monitoring, the most effective place to devote the greatest effort is at the source, where observation of water quality degradation allows enough time for minimizing the problem and for establishing a warning procedure. After contamination has affected enough of the aquifer, monitoring no longer becomes a protective measure but simply informs the regulator or the user of long-term changes. Also, random placement of monitoring wells on a regional basis can provide misleading information, because important plumes and individual bodies of contaminated ground water are overlooked. Monitoring of discharge points serves as a safety precaution and helps define trends. For this reason, it cannot be eliminated from the monitoring program.

The principal abatement procedure for surface-water problems is to eliminate or correct the source of contamination. Because streams are subject to the cleansing action of turbulent flow and the purifying effects of air, light, and biological organisms, they can recover quickly. The opposite is true for ground water. Removal of the source prevents the problem from becoming worse but does not lead to a cleansing of the aquifer. In addition, clean-up procedures such as removal of the contaminant by means of pumping wells followed by treatment of the water is almost never economically or technically feasible. For example, pumping may require the use of an inordinate number of wells and a complex collection and treatment system, which is only temporary and difficult to support with either private or public funds. Although containment of contaminants within a selected portion of an aquifer has been achieved to various degrees in certain instances, complete removal is rarely attempted and has not been successful.

IMPORTANCE OF THE GROUND-WATER RESOURCE

At least one half of the population of the United States depends upon ground water as a source of drinking water. Of the total population, 29 percent use ground water delivered by community systems and another 19 percent have their own domestic wells. In addition, millions of Americans drink ground water from wells serving industrial plants, office buildings, restaurants, gas stations, recreational areas, and schools. Practically none of the domestic wells in the nation are subject to routine or even initial evaluation of water quality. Few of the several hundred thousand small water systems supplying industrial establishments, schools, etc., are monitored. Figure 4 shows those states where ground water represents the source of drinking water for more than half the population.

NATURE AND EXTENT OF THE RESOURCE

At almost any location, ground water may be tapped to provide a supply sufficient for single-family domestic use, and more than one third of the nation is underlain by aquifers generally capable of yielding at least 100,000 gpd (380 cu m/day) to an individual well. In many regions, ground water is the only economic and high quality water source available. In others, ground water can be developed at a fraction of the cost of surface water.

Ground water in aquifers across the nation is generally suitable for human consumption with little or no treatment necessary, except for disinfection where large, piped water-supply systems are involved. Salinities tend to be higher in arid

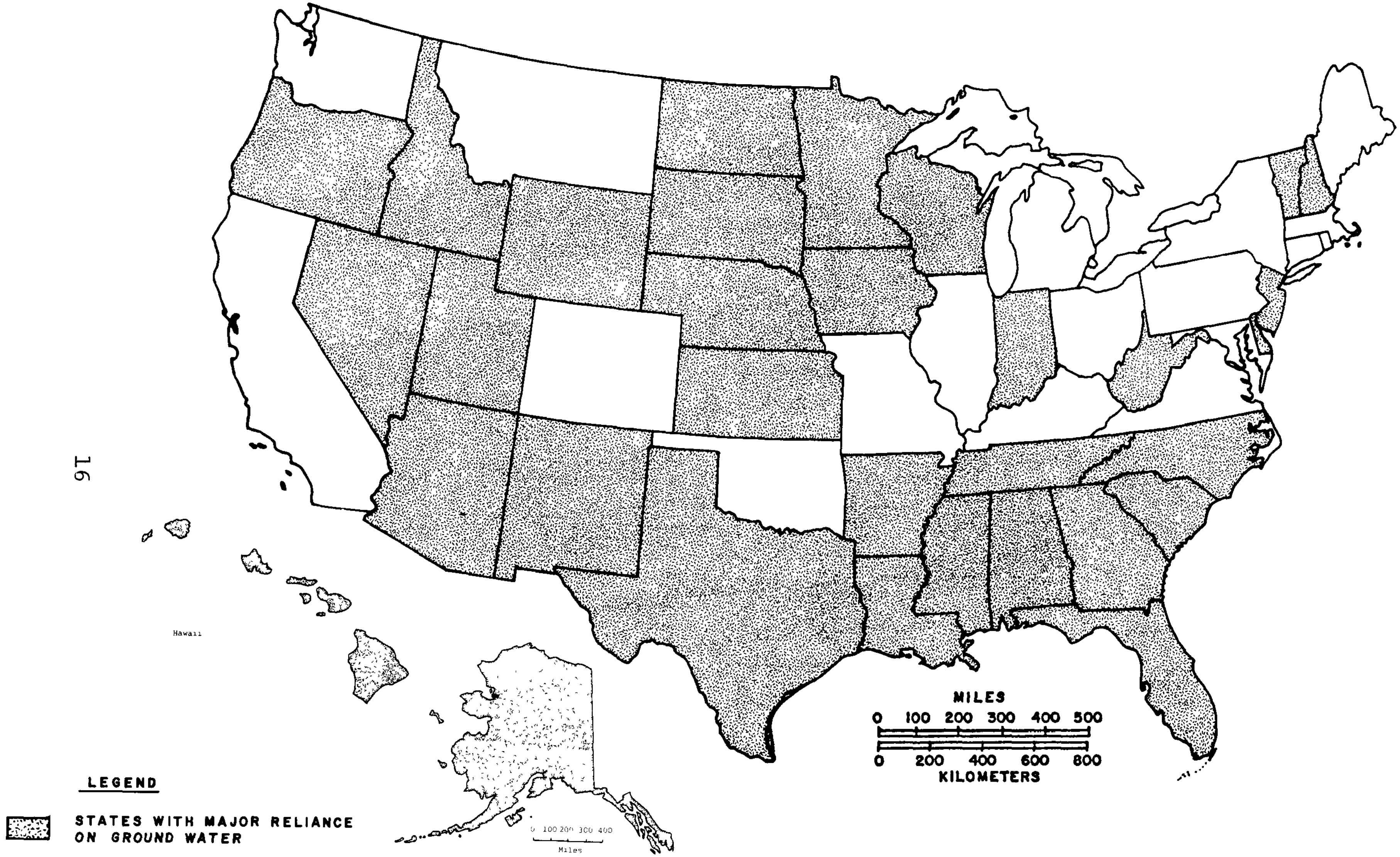


Figure 4. Dependence of United States population on ground water as a source of drinking water. 1)

regions and areas where drainage is poor.

HOW GROUND WATER IS CONTAMINATED

Innumerable waste materials and natural and man-made products, with the potential to contaminate ground water, are stored or disposed of on or beneath the land surface. Contaminants found in ground water cover the entire range of physical, inorganic chemical, organic chemical, bacteriological, and radioactive parameters.

Contaminants that have been introduced into ground water can move horizontally or vertically, depending on the comparative density and natural flow pattern of the water already contained in the aquifer. They tend to travel as a well-defined slug or plume but can be reduced in concentration with time and distance by such mechanisms as adsorption, ion exchange, dispersion, and decay. The rate of attenuation is a function of the type of contaminant and of the local hydrogeologic framework, but decades and even centuries are required for the process to be completely effective.

Under the right conditions and given enough time, contaminating fluids invading a body of natural ground water can move great distances, hidden from view and little changed in toxicity by the processes of attenuation. The eventual point of discharge of the contaminated ground-water body can be a well used as a drinking water source.

INDUSTRIAL WASTE-WATER IMPOUNDMENTS

Industrial waste-water impoundments are a serious source of ground-water contamination because of their large number and their potential for leaking hazardous substances which are relatively mobile in the ground-water environment. In some heavily industrialized sections of the nation, regional problems of ground-water contamination have developed where the areal extent and the toxic nature of the contaminants have ruled out the use of ground water from shallow aquifers. Contaminated ground water originating from impoundments at isolated industrial establishments can be even more important because of the potential for migrating to local water-supply wells with no warning.

Either by design, or by accident or failure, surface impoundments of industrial effluent can cause ground-water contamination because of leakage of waste waters into shallow aquifers. Potential contaminants cover the full range of inorganic chemicals and organic chemicals normally contained in industrial waste waters. Those documented as having degraded ground-water quality include phenols, acids, heavy metals, and cyanide.

United States' industries treat about 5,000 billion gal./yr (18 billion cu m/yr) of waste water before discharging it to the environment. Of this volume, about 1,700 billion gal. (6.4 billion cu m) are pumped to oxidation ponds or lagoons for treatment or as a step in the treatment process. Unknown quantities of industrial wastes are also stored or treated in other types of impoundments, such as basins and pits. Based on standard leakage coefficients and volumes of waste waters discharged, it is estimated that more than 100 billion gal./yr (380 million cu m/yr) of industrial effluents enter the ground-water system. This source of contamination is one of the most frequently reported, in spite of the almost complete lack of formal ground-water monitoring programs. Figure 5 shows principal regions in which waste water is discharged to industrial impoundments.

One option to correct leaking impoundments is the use of an impermeable barrier or liner. A second is to replace wastewater treatment operations now performed in ponds and lagoons with such alternatives as clarifiers, filtration or centrifugation equipment, and digestion (anaerobic, aerobic).

Impoundments of industrial wastes are normally not subject to any special regulations unless it is shown that they may affect surface- or ground-water quality. In order to overcome this burden of proof, a few states have developed specific regulations covering such aspects as design of the facility to guard against or minimize leakage, reporting types and volumes of effluent, and installation of monitoring wells.

LAND DISPOSAL OF SOLID WASTES

Solid waste land disposal sites can be sources of groundwater contamination because of the generation of leachate caused by water percolating through the bodies of refuse and waste materials. Precipitation falling on a site either becomes runoff, returns to the atmosphere via evaporation and transpiration, or infiltrates the landfill. Contamination problems are more likely to occur in humid areas, where the moisture available exceeds the ability of the waste pile to absorb water.

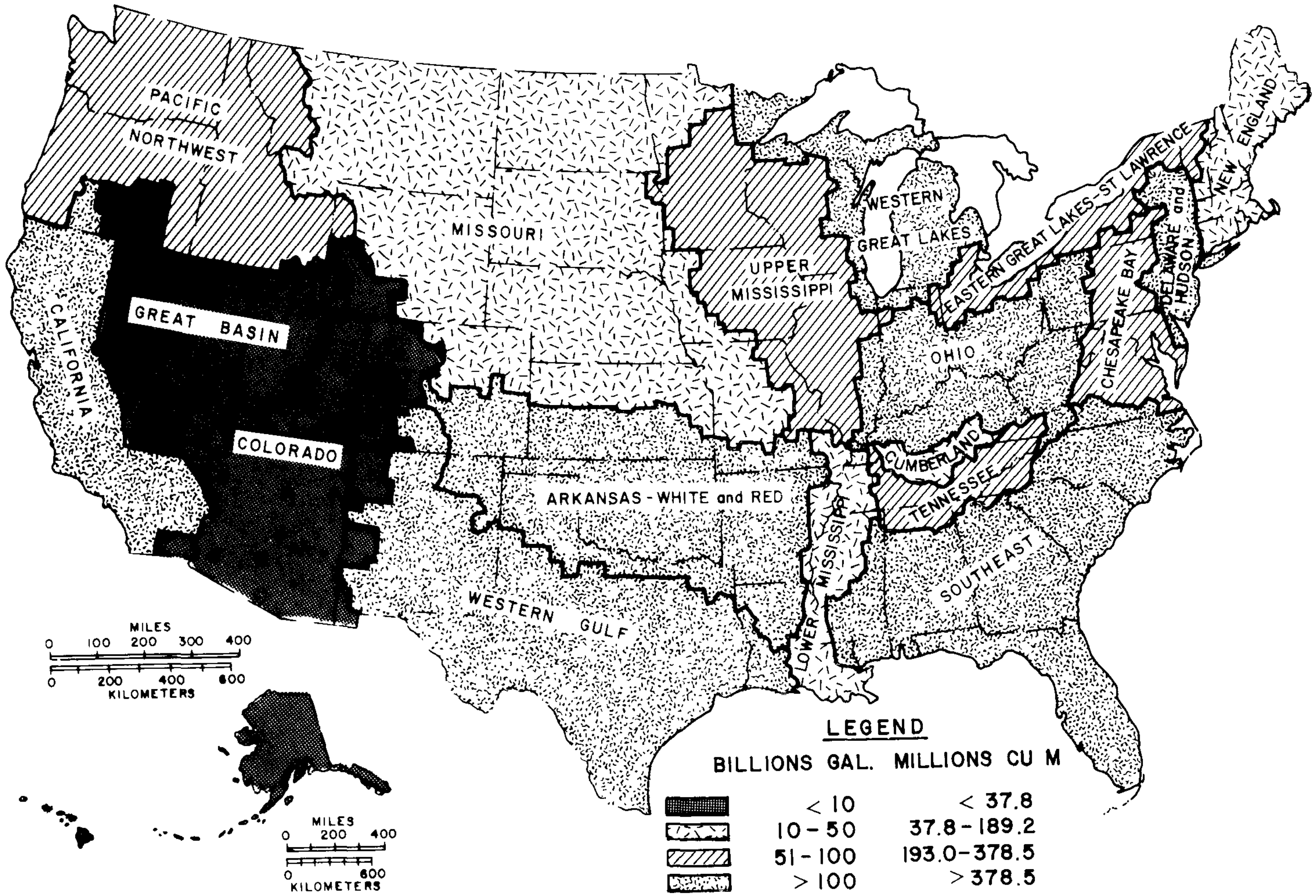


Figure 5. Total industrial waste water treated in ponds and lagoons, 1968.

Leachate is a highly mineralized fluid containing such constituents as chloride, iron, lead, copper, sodium, nitrate, and a variety of organic chemicals. Where manufacturing wastes are included, hazardous constituents are often present in the leachate (e.g., cyanide, cadmium, chromium, chlorinated hydrocarbons, and PCB). The particular makeup of the leachate is dependent upon the industry using the landfill or dump. Another problem is the disposal of low-level radioactive wastes.

There are about 18,500 land disposal sites which accept municipal wastes, of which only about 20 percent are "authorized." Most are open dumps, or poorly sited and operated landfills, and most receive some industrial wastes. There is no national inventory available on privately owned industrial land disposal sites. However, it is estimated that 90 percent of industrial wastes that are considered hazardous are landfilled, mainly because it is the cheapest waste-management option. Table 2 summarizes the data on 60 selected cases of ground-water contamination in the northeastern United States caused by leachate from land disposal sites.

Problems presently associated with existing or abandoned dumps and landfills should not be considered in the same category as potential problems at new, properly designed sanitary landfills because there are methods available for minimizing environmental effects and managing leachate production. Proper siting in locations where potential contamination of ground water is limited is one method. Reduction of leachate formation by use of selected cover materials and surface grading of the refuse pile is another. Also promising but costly are such techniques as pre-treatment capable of reducing the volume or solubility of the waste, detoxification of hazardous wastes prior to disposal, and collection of the leachate by means of impermeable barriers or liners, followed by treatment.

There is no effective Federal regulatory control of land disposal of solid waste except as it may enter navigable waters. Forty-four states have statutes which prohibit the disposal of solid waste without a permit. The range of requirements for state permit systems extends from simple notification that a facility exists to detailed site descriptions including the results of soil borings and sampling of baseline ground-water quality. About 15 states have regulations limiting land disposal of hazardous wastes.

Table 2. SUMMARY OF DATA ON 42 MUNICIPAL AND 18 INDUSTRIAL LANDFILL CONTAMINATION CASES.

Findings	Type of Landfill	
	Municipal	Industrial
Assessment of principal damage		
Contamination of aquifer only	9	8
Water supply well(s) affected	16	9
Contamination of surface water	17	1
Principal aquifer affected		
Unconsolidated deposits	33	11
Sedimentary rocks	7	3
Crystalline rocks	2	4
Type of pollutant observed		
General contamination	37	4
Toxic substances	5	14
Observed distance traveled by pollutant		
Less than 100 feet	6	0
100 to 1,000 feet	8	4
More than 1,000 feet	11	2
Unknown or unreported	17	12
Maximum observed depth penetrated by pollutant		
Less than 30 feet	11	3
30 to 100 feet	11	3
More than 100 feet	5	2
Unknown or unreported	15	10
Action taken regarding source of contamination		
Landfill abandoned	5	6
Landfill removed	1	2
Containment or treatment of leachate	10	2
No known action	26	8
Action taken regarding ground-water resource		
Water supply well(s) abandoned	4	5
Ground-water monitoring program established	12	2
No known action	26	11
Litigation		
Litigation involved	8	5
No known action taken	34	13

SEPTIC TANKS AND CESSPOOLS

Septic tanks and cesspools rank highest in total volume of waste water discharged directly to ground water and are the most frequently reported sources of contamination. However, most problems are related to individual homesites or subdivisions where recycling of septic fluids through aquifers has affected private wells used for drinking water. Except in situations where such recycling is so quick that pathogenic organisms can survive, the overall health hazard from on-site domestic waste disposal is only moderate, with relatively high concentrations of nitrate representing the principal concern.

Twenty-nine percent of the population, representing about 19.5 million single housing units, dispose of their domestic waste through individual on-site disposal systems. Almost 17 million of these housing units use septic tanks or cesspools. Regional ground-water quality problems have been recognized only in those areas of the greatest density of such systems, primarily in the northeast and southern California. Table 3 lists those counties that have 50,000 or more housing units with on-site domestic waste disposal systems.

Where the density of on-site disposal systems has created problems, collection of domestic waste water by public sewers and treatment at a central facility is the most common alternative. Other alternatives, which are generally limited to special situations where natural conditions or restrictive codes rule out conventional septic tank systems, include aerobic treatment tanks, sand filters, flow reduction devices, evapotranspiration systems, and artificial soil (mounds) disposal systems.

Where sewer systems are not economically feasible, prevention of ground-water quality problems has normally been attempted by low density zoning at the local government level, although increased regulation of septic tank siting, construction and design is emerging at the state government level. More than half the states now participate in septic tank permitting or regulation of some type, and a large number are providing local agencies with data to aid in land-use planning as applied to septic tank density.

Table 3. COUNTIES WITH MORE THAN 50,000 AND COUNTIES WITH MORE THAN 100,000 HOUSING UNITS USING ON-SITE DOMESTIC WASTE DISPOSAL SYSTEMS.

More than 50,000

Jefferson, Alabama
Riverside, California
San Bernadino, California
Fairfield, Connecticut
Hartford, Connecticut
New Haven, Connecticut
Broward, Florida
Duval, Florida
Hillsborough, Florida
Jefferson, Kentucky
Bristol, Massachusetts
Middlesex, Massachusetts
Norfolk, Massachusetts
Plymouth, Massachusetts
Worcester, Massachusetts
Genesee, Michigan
Oakland, Michigan
Monmouth, New Jersey
Multnomah, Oregon
Westmoreland, Pennsylvania
Davidson, Tennessee
King, Washington
Pierce, Washington

More than 100,000

Los Angeles, California
Dade, Florida
Nassau, New York
Suffolk, New York

COLLECTION, TREATMENT, AND DISPOSAL OF MUNICIPAL WASTE WATER

Municipal waste water follows one of three direct routes to reach ground water: leakage from collecting sewers, leakage from the treatment plant during processing, and land disposal of the treatment-plant effluent. In addition, there are two indirect routes: effluent disposal to surface-water bodies which recharge aquifers, and land disposal of sludge, which is subject to leaching. Although the volume of waste water entering the ground-water system from these various sources may be substantial, there have been few documented cases of hazardous levels of constituents of sewage or storm water affecting well-water supplies. However, the impact on ground-water quality resulting from the collection, treatment, and disposal of municipal waste water has not been studied in detail.

Untreated sewage is principally composed of domestic wastes. In areas where manufacturing is also served by the community system, the waste products of industry can add important potential contaminants. Storm runoff from streets, parking lots, and roofs contributes salts, inorganic chemicals, and organic matter which have been deposited on exposed surfaces.

According to the 1970 U. S. Census of Housing, the domestic waste from 71 percent of housing units is collected by public sewer lines and piped to central treatment facilities. Figure 6 shows the distribution of population served by public sewer systems.

About 160 million people are served by 500,000 mi (800,000 km) of sewer lines. The total volume of sewage is approximately 15 bgd (57 million cu m/day). More than 5,000 of the almost 22,000 treatment plants in the nation have waste stabilization ponds, which are seldom lined and almost never monitored with wells. Of the more than 2 bgd (7.6 million cu m/day) of sewage treatment plant effluent discharged to the land, a large proportion does not meet secondary treatment standards.

About the only control of potential ground-water contamination related to leaky sewers is the specification by many states of minimum distances between a proposed public supply well and a sewer line. Conformance with pressure test requirements on new sewer line installations in many areas aids in minimizing exfiltration problems. Municipal lagoons and ponds for the retention of waste water are parts of sewage

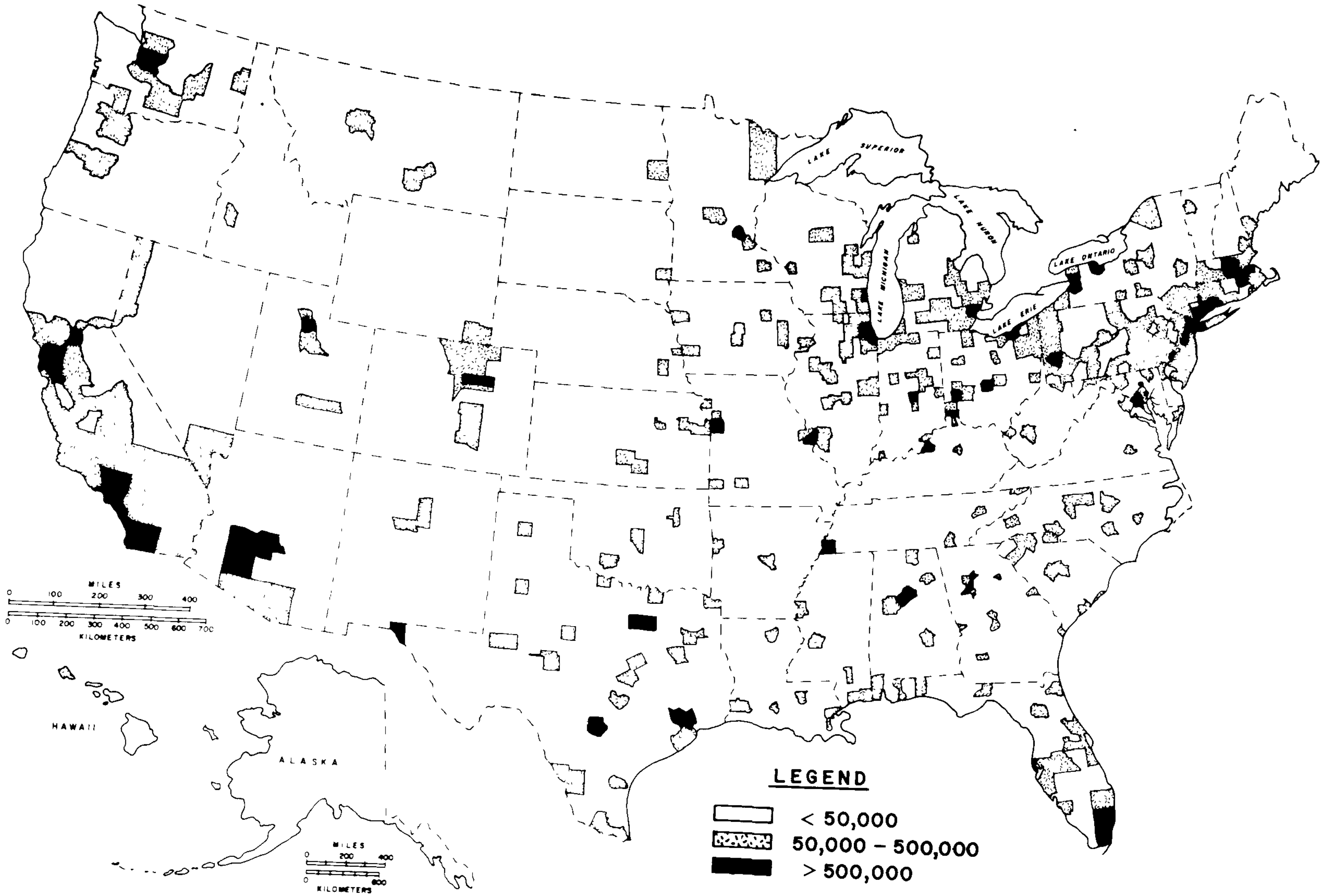


Figure 6. Number of people using public sewer systems for disposal of domestic waste (by county).

treatment facilities, the construction and operation of which are supervised by state health or environmental departments. In addition, where Federal grants are involved, the design of the impoundment comes under the scrutiny of the EPA. Thus, in the construction of new lagoons and ponds, potential effects on ground-water quality are given consideration. A number of states also require permits for municipal sewage impoundments. Spraying of sewage effluent and other forms of land disposal of sewage wastes are specifically regulated in only a few states. Most states review such practices on a case-by-case basis.

LAND SPREADING OF SLUDGE

Municipal and industrial sludge is the residue remaining after treatment of waste water. The impact of diffuse land spreading of municipal and industrial sludge on ground water is not documented even though the potential for contamination exists. Less than one percent of the present municipal sludge disposal facilities are monitored for effects on water quality. Even fewer industrial sludge sites are monitored because this potential source of ground-water contamination has received less attention than municipal sources.

Sludge may be a product of physical, biological, or chemical treatment or a combination thereof. Ground-water quality degradation can be caused by land spreading of sludge because organisms (such as viruses) and chemical ions and compounds can be leached by precipitation and carried in percolate to ground water.

Land and air (through incineration) remain the depositional areas for an ever increasing volume of sludge from a growing population and from higher degrees of waste-water treatment, the latter brought on by more stringent environmental protection of rivers, lakes, the ocean, and the atmosphere. Most municipal and industrial sludge now goes to landfills and impoundments. As controls over these two methods of disposal become more restrictive with respect to type of waste accepted, the amount of sludge diverted to land-spreading sites will increase rapidly.

In the United States, municipal sludge production amounts to about 5,000,000 dry tons/yr (4,540,000 dry tonnes/yr). Accurate data on quantities of industrial sludge are not available. However, the total volume certainly exceeds municipal sludge production by many times. The organic and inorganic chemicals industries and coal-fired utilities are the largest contributors of residues and account for over half of the total production. Industrial expansion and growing pollution control activities should increase the volume of industrial sludges dramatically over the next 10 years.

The key to correct management combines site selection with sludge composition, application rates, and land use (crops). Of major importance to ground water is the availability of soil, such as a loam or silt loam, that is the most efficient for attenuating contaminants.

In most states, the basic provision of law applicable to land spreading of municipal and industrial sludges is the all inclusive prohibition against polluting waters of the state. Before action can be taken, the presence of a contamination problem must be established. In a few instances, control over sludge disposal can be asserted where states have enacted "potential pollution" statutes which include sludge spreading in the same provisions as those that apply to waste lagoons and landfills. Other states have developed special laws that apply to disposal of hazardous or general industrial process wastes including sludges.

BRINE DISPOSAL FROM PETROLEUM EXPLORATION AND DEVELOPMENT

Disposal of brine from oil and gas production activities has been a major cause of ground-water contamination in areas of intense petroleum exploration and development (see Figure 7). The principal problem has been related to the long-term practice of discharging to unlined pits, which is now almost universally prohibited. The large number of instances of ground-water contamination from brine disposal stem mainly from days when there was very little regulation of oil exploration and development. Today, the major problem is discharge of saline water from abandoned oil and gas wells rather than disposal of waste brine through injection or secondary recovery wells at active petroleum recovery fields.

The first method of brine disposal was uncontrolled discharge to streams and ditches, and later to evaporation pits. These pits were unlined shallow excavations which could leak salts and minerals into shallow fresh-water zones. Evaporation pits range in area from tens of square feet to a few acres. It is impossible to even roughly estimate the total number, areal extent, and brine input to such sources of contamination, especially since so many have been abandoned over the

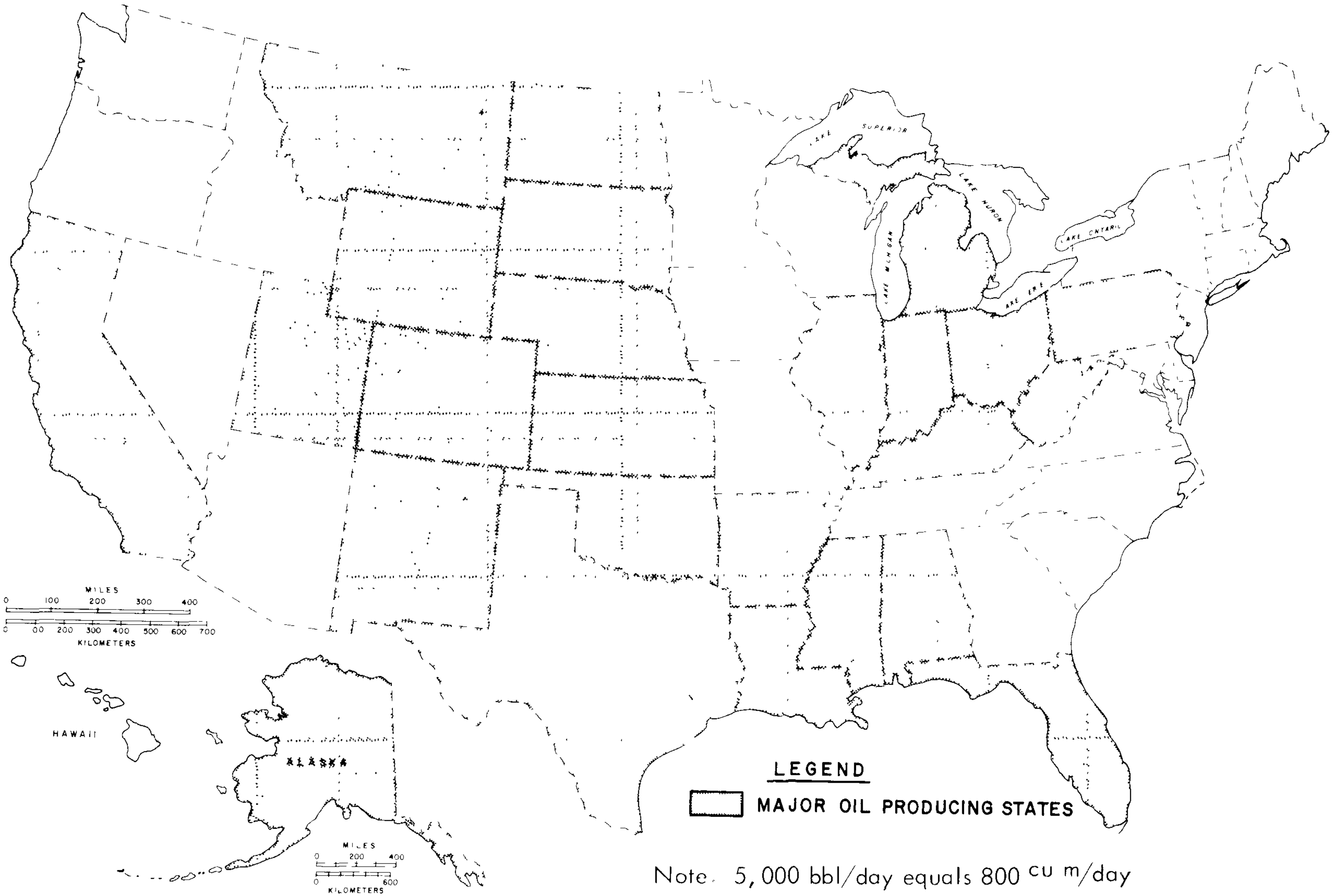


Figure 7. Major oil producing states (more than 5,000 barrels per day in 1974).

past decade.

Most oil-field brines today are returned to oil-producing zones or deep saline aquifers through old production wells or brine injection wells for the purpose of water flooding, or just as a disposal method. However, many of these wells are poorly designed for injection, and they offer the opportunity for the salt water to enter fresh-water formations through ruptured or corroded casings.

A tremendous volume of oil-field brine is produced every day. Some states keep detailed records, others none at all. In 1963, the Interstate Oil Compact Commission made a study to determine the production and ultimate fate of brine. Of the 24 states for which data were obtained, almost 24 million bbl (3.84 million cu m) were produced daily that year. About 8 million bbl/day (1.28 million cu m/day) were reinjected for water flood and 9 million bbl/day (1.44 million cu m/day) were reinjected for disposal only. Unlined pits received about 3 million bbl/day (480,000 cu m/day). Brine production in some states has increased significantly since 1963. For example, brine production in California had increased by about 2 million bbl/day (320,000 cu m/day) by 1974.

Enactment of state oil and gas laws has been primarily motivated by recognition of the need for orderly development of oil fields in order to prevent waste of petroleum resources and to stop losses that result from unregulated competition. Although such laws reveal an awareness of the close relationship of petroleum activities to ground-water resources, they are principally concerned with economics of petroleum production and not environmental considerations. In almost every state, disposal of brines to streams, rivers, ditches, and unlined pits is prohibited. Many states allow use of lined evaporation pits and most regulate the use of brine injection wells.

DISPOSAL OF MINE WASTES

All forms of mining can result in products and conditions that may contribute to ground-water contamination. The patterns of ground-water recharge and movement responsible for the distribution of contaminants are highly variable and almost entirely dependent upon the mining practice itself and such local conditions as geology, drainage, and hydrology. Although every mine is a potential contamination hazard, few studies of the effects on ground-water quality have been carried out.

With both surface and underground mining, refuse piles and slurry lagoons are probably the major potential sources of ground-water contamination. Where aquifers underlie these sources, water with a low pH (except in arid regions) and an elevated level of total dissolved solids can percolate to ground water.

Coal mining is a major industry in the United States. In 1973, 592 million tons (537 million tonnes) of bituminous coal were produced. Another 108 million tons (98 million tonnes) were rejected from the preparation plants. Between 1930 and 1971, almost 200,000 acres (81,000 ha) were used for disposal of coal mining wastes, less than 27,000 acres (11,000 ha) of which have been reclaimed. Past surface mining has affected 1.3 million acres (0.5 million ha) of land, and about 4,900 active mines were disturbing 75,000 acres (30,000 ha) annually.

According to the U. S. Census Bureau figures, five states -- Pennsylvania, West Virginia, Alabama, Illinois, and Kentucky -- each have coal mining operations which discharged more than 5 billion gal. (19 million cu m) of waste water in 1972. Other states discharging high volumes of waste water are Ohio, Indiana, and Virginia.

Metal mining in the United States has also been substantial, and in 1972 the number of active mines producing crude metal ore was about 800. The quantity of tailings disposed of in ponds by the metal mining industry alone is estimated at 250 million tons (230 million tonnes) per year. Phosphate rock mines dominate the non-metal category and produced over 137 million tons (124 million tonnes) of crude ore and 426 million tons (387 million tonnes) of total material handled. Figure 8 indicates those states in which significant volumes of waste water are discharged from metal and non-metal mining and ore processing operations.

Procedures for the abatement of ground-water contamination from mining waste disposal practices can be divided into two broad categories. The first consists of methods for control of seepage and infiltration of surface water and ground water into the mine. The second is treatment to reduce levels of contaminants in the waste. All are very costly processes and have not been practiced to any significant degree.

Most states must rely on all-encompassing water pollution control statutes in order to regulate disposal of mine wastes. There are Federal regulations which pertain solely to the disposal of coal mine wastes. However, these focus primarily on worker safety and have little mention of water pollution, es-

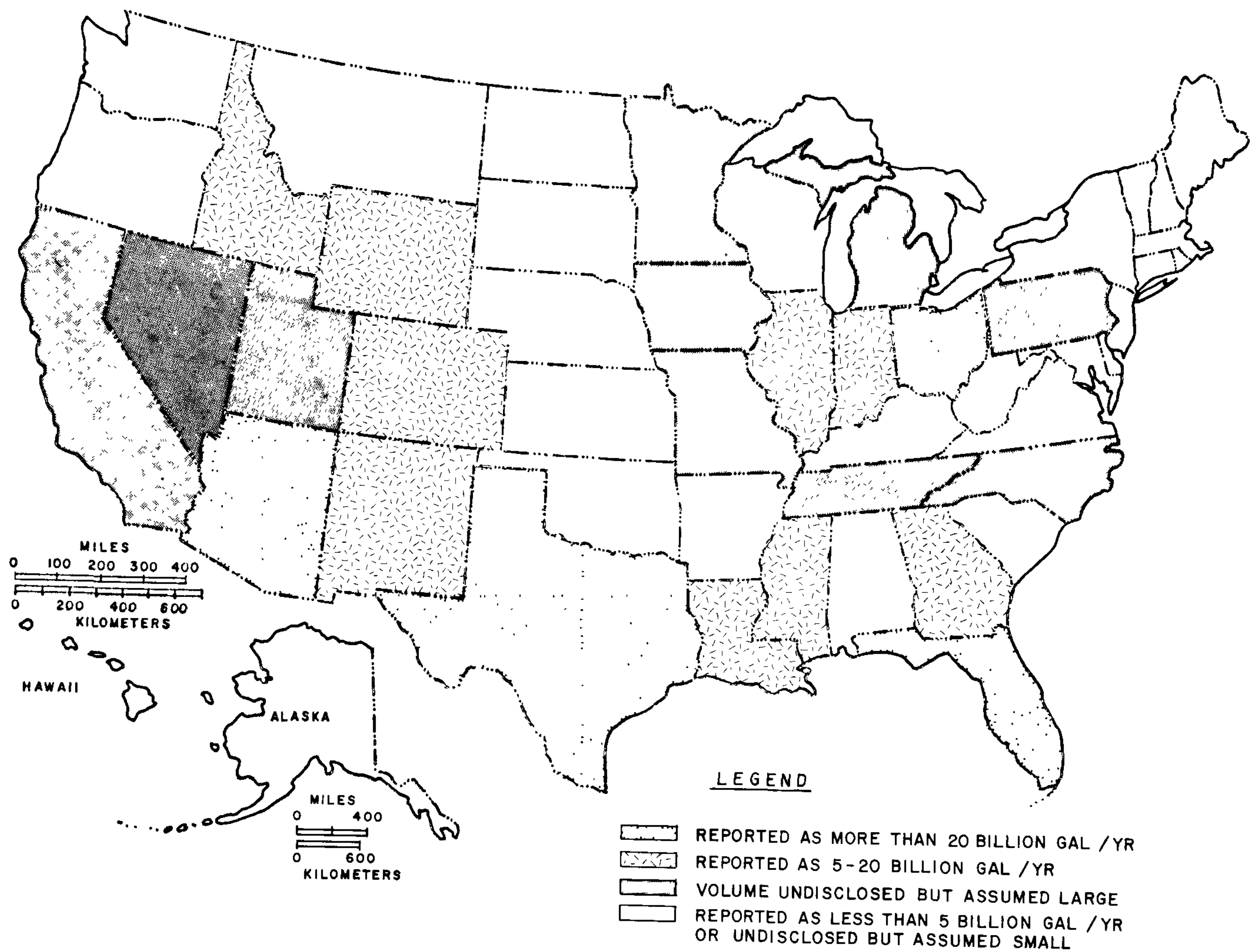


Figure 8. States in which significant volumes of waste water are discharged from mining and ore processing operations (excluding coal and petroleum), 1972.

pecially as related to ground water.

WASTE DISPOSAL THROUGH WELLS

Industrial waste, sewage effluent, spent cooling water, and storm water are discharged through wells into fresh- and saline-water aquifers in many parts of the United States. The greatest attention in existing literature has been given to deep disposal of industrial and municipal wastes through wells normally drilled a thousand feet or more into saline aquifers. A total of 322 such wells have been constructed in 25 states, and 209 are operating. They pose a comparatively small potential for contamination when compared to the tens of thousands of shallow wells injecting contaminants directly into fresh-water aquifers.

Irrigation and storm-water drainage wells and septic tank effluent disposal wells total about 15,000 in Florida, Oregon, and Idaho alone. On Long Island, New York, approximately 1,000 diffusion wells inject about 80 million gpd (300,000 cu m/day) from air conditioning or cooling systems into two of the principal aquifers tapped for public water supply. Thousands more are used for disposal of storm-water runoff. In a few areas, principally in limestone and basalt regions where openings in the rock are large enough to transmit high volumes of liquid (see Figure 9), the practice of discharging raw sewage and sometimes industrial waste in shallow fresh-water aquifers has not been uncommon.

Of wells used for disposal of industrial and municipal wastes in saline aquifers, few failures have been reported. This is due to the strict regulation and permit system generally enforced by public agencies in those states which allow construction of this type of well. On the other hand, shallow wells completed in potable-water aquifers and used for waste disposal have received little attention. This has resulted in a number of documented cases of severe ground-water contamination, frequently from the illegal use of wells for the disposal of various types of hazardous wastes.

Under general water pollution control laws, most states automatically rule out the use of wells for injection of either sewage or industrial wastes into fresh-water aquifers. In a few states, where drainage wells have been a popular means for disposal of domestic waste water, storm runoff and irrigation runoff, programs are underway to eventually eliminate this practice. Federal regulations only cover industrial injection wells, municipal sewage disposal wells, irrigation

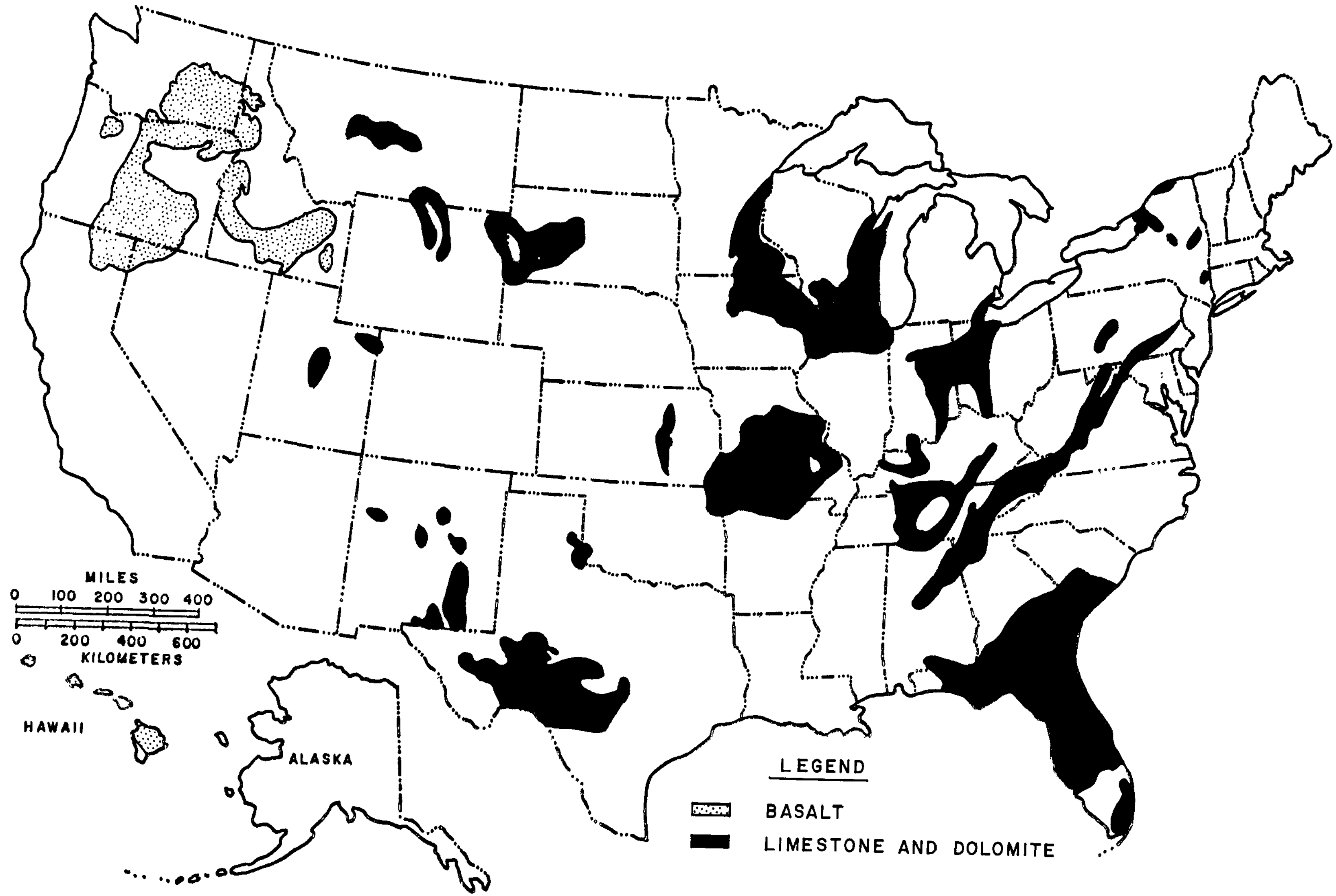


Figure 9. Rock aquifers, containing potable water, most likely to be used for disposal wells.

drainage wells, and storm-water disposal wells.

DISPOSAL OF ANIMAL FEEDLOT WASTE

The generation and disposal of large quantities of animal waste at locations of concentrated feeding operations is a relatively new environmental problem. Case histories of actual contamination of ground water caused by animal feeding operations are almost non-existent. However, because such practices are relatively new, assessment of potential problems is still underway.

There are three primary mechanisms of ground-water contamination from animal feedlots and their associated treatment and disposal facilities: (1) runoff and infiltration from the feedlots themselves, (2) runoff and infiltration from waste products collected from the feedlots and disposed of on land, and (3) seepage or infiltration through the bottom of a waste lagoon. The principal contaminants are phosphate, chloride, nitrate, and in some cases, heavy metals.

Cattle are the most serious potential problem in terms of the volume of waste produced, but sheep, poultry, and hog feeding operations also represent potential sources of ground-water contamination. During its 120- to 150-day stay in the feedlot, each beef animal will produce over one-half ton (0.45 tonne) of manure on a dry weight basis. In January 1975, there were almost 10 million cattle in feedlots of more than 1,000-head capacity.

The two leading cattle feedlot regions, the Corn Belt and the Northern Plains, form a grain-farming and livestock-growing belt that extends easterly from the south-central part of the Northern Plains, traverses the Missouri and Mississippi Rivers and terminates in western Ohio. Other significant feedlot areas are found in California, Arizona, New Mexico, Texas, and Washington. Principal states for poultry raising are located in the south, for hogs in the midwest, and for sheep in the southwest and in the far west.

Application of manure to land for its fertilizer and soil conditioner value is the classic system through which manure has been utilized. Several methods have been proposed for converting manure to energy products, the principal one involving thermochemical processes for conversion to methane, oil, and/or synthesis gas.

"Concentration animal feeding operations" are regulated under the Federal Water Pollution Control Act Amendments of 1972, and thus may be required to have a permit as a "point source" under the NPDES. State animal-feedlot regulations typically apply to the situation where the ratio of the number of animals to land area is high.

PRINCIPAL SOURCES OF GROUND-WATER CONTAMINATION NOT RELATED TO WASTE-DISPOSAL PRACTICES

Aside from the possibility of contamination of ground water from present-day, waste-disposal practices, there are numerous other sources that can cause degradation of water quality. Few regional and national assessments of ground-water contamination problems have been undertaken. However, without exception, the number of documented cases reported is evenly divided between incidents related to waste-disposal practices and those related to non-waste disposal problems. Spills rank highest in reported incidents, with abandoned oil and gas wells, water wells, and highway deicing salts also of prime importance. Only salt-water encroachment in coastal regions has received major attention from regulatory agencies and because of this is adequately controlled in most critical areas.

EXISTING FEDERAL LEGISLATION

Conscious effort and legislation toward comprehensive water pollution control began with the Water Pollution Control Act of 1948. This Act was primarily concerned with abatement of stream pollution, and it directed the Surgeon General to "prepare or adopt comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary conditions of surface and underground waters."

Several other pieces of Federal legislation since 1948 provide further legal methods to protect ground water from contamination.

1. Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) establishes a planning function which provides for areawide and statewide waste treatment management. This planning must specifically include a process to identify and control pollution from surface and underground mine runoff, the disposal of re-

sidual waste, and the disposal of pollutants on land or in subsurface excavations. EPA's role, as set forth by Section 304(e) is to provide guidance and information, but EPA has no implementation authority.

Section 402 of PL 92-500 establishes the National Pollutant Discharge Elimination System (NPDES), which is a program for issuing permits for point source discharges of pollutants. Section 402 also requires states to control the discharge of pollutants into wells. However, Section 502 excludes from the definition of pollutants "water, gas, or other material which is injected into a well to facilitate production of oil or gas, or water derived in association with oil or gas production and disposed of in a well, if the well used either to facilitate production or for disposal purposes is approved by authority of the state in which the well is located, and if such state determines that such injection or disposal will not result in the degradation of ground or surface water resources." This exclusion therefore removes wells used in association with oil and gas production from regulations under Section 402.

2. The Solid Waste Disposal Act of]965, as amended in 1970, contains no specific reference to ground water. However, guidelines developed under the Act provide for groundwater protection resulting from polluting activities and surface drainage and also for site development to minimize the impact on ground water. These guidelines are only mandatory for Federal agencies, but they serve as recommended practices for non-Federal agencies.

3. The National Environmental Policy Act (NEPA) of 1969 (PL 91-190) requires that all Federal agencies prepare environmental impact statements on major Federal or Federally regulated actions significantly affecting the quality of the environment. EPA has promulgated regulation for implementation of NEPA which lists ground-water protection as a significant parameter in determining the need for an EIS.

4. The discharge of radioactive wastes has been regulated from the beginning. However, there have been many significant problems, and an Interagency Work Group consisting of representatives of the Nuclear Regulatory Commission (NRC), the Energy Research and Development Agency (ERDA) and EPA has been formed to evaluate radioactive waste management and disposal.

5. The Safe Drinking Water Act of 1974 (PL 93-523) requires

the regulation of underground injection which may endanger underground drinking water sources. The provisions of the Act will produce a Federal/state cooperative effort which is based on Federally set minimum standards and regulations administered by the states. The practices to be covered under the Act include "deep" and "shallow" waste disposal wells, oil-field brine disposal wells and secondary recovery wells, and engineering wells.

Section 1424(e) of the Act (the Gonzalez Amendment) provides that if EPA determines an area has an aquifer which is the sole or principal drinking water source and which, if contaminated, will cause a significant hazard to health, EPA may delay or stop commitment of any Federal financial assistance to projects which may result in contamination of the aquifer.

STATE AND LOCAL ALTERNATIVES FOR GROUND-WATER QUALITY PROTECTION

There are a number of requirements that are basic to all state and local ground-water protection programs. Similar to Federal activities, control over ground-water quality has been given a low priority when compared to surface water. This has been due to deficiencies in existing legislation, the lack of funds available for proper staffing, and the diverse interests and priorities of existing agencies.

For maximum effectiveness, rules and regulations for protecting ground water should be designed to: (1) prevent and control unwanted contamination and degradation of both ground- and surface-water quality; (2) provide data necessary to evaluate the nature and areal extent of ground-water contamination and the number of sources of contamination; (3) provide a basis for correcting or mitigating existing cases of ground-water contamination; and (4) provide a regulatory framework within which aquifers can be used for waste treatment and storage.

There are two approaches to the problem of protecting ground-water resources. One is to look at the underground water itself as the resource to be managed and to concentrate on limiting waste discharges and preventing causes of contamination. This first method is the one used to control air and surface-water pollution. It is also the most popular basis for ground-water control regulations.

A second approach is to take into account the ability of aquifers to treat and store wastes and to consider these characteristics as the prime resource to be managed or controlled. The second method is not in common usage, but may become more popular as ground-water technology becomes more sophisticated. An example of this approach could be based upon the possibility of states and local governments acquiring ownership of aquifer pore space (storage capacity) through eminent domain proceedings or other methods.

When faced with the multiplicity of ground-water contamination causes and sources, the question becomes "to permit or not to permit." To deal with this problem, these sources and causes have been divided into four categories (Table 4). The first two categories concern discharges of contaminants that are wastes or waste waters, the third category concerns discharges of contaminants that are not wastes, and the fourth category consists of those causes of ground-water quality degradation not related to discharges. Some of the sources or causes of ground-water contamination could fall under more than one category, for example, some lagoons may be designed to discharge to land and ground waters.

As a general rule, all Category I causes will require a discharge or injection control permit for each project. Exceptions can be made, for example, on the basis of existing permit systems. A regulatory agency can also decide for political or economic reasons, to simply exempt the discharge activity from permit requirements if the impact on aquifers and underground waters is not considered significant. Category II causes will require approval of construction standards (again, exceptions can be made). A permit for Category II could be required for activities which posed an exceptional threat of ground-water contamination such as lagoons and landfills. Category III causes will require facility construction standards and/or guidelines and manuals (e.g., tons/mile limits on highway deicing salts, corrosion-proof buried storage tanks, covered stockpiles). For Category IV causes, other types of regulatory controls will be needed in addition to facility construction standards, guidelines and manuals (e.g., controls on ground-water withdrawals, limits on discharges of contaminants to streams, and constraints on land use).

Table 4. CLASSIFICATION OF SOURCES AND CAUSES OF GROUND-WATER POLLUTION USED IN DETERMINING LEVEL AND KIND OF REGULATORY CONTROL.

WASTES		NON-WASTES	
CATEGORY I	CATEGORY II	CATEGORY III	CATEGORY IV
Systems, facilities or activities designed to discharge waste or waste waters (residuals) to the land and ground waters	Systems, facilities or activities which may discharge wastes or waste waters to the land and ground waters	Systems, facilities or activities which may discharge or cause a discharge of contaminants that are not wastes to the land and ground waters	Causes of ground water pollution which are not discharges
LAND APPLICATION OF WASTE WATER - sprary irrigation, infiltration-percolation basins, overland flow	SURFACE IMPOUNDMENTS - waste holding ponds, lagoons and pits	BURIED PRODUCT STORAGE TANKS AND PIPELINES	SALT-WATER INTRUSION - sea water encroachment, upward coning of saline ground water
SUB-SURFACE SOIL ABSORPTION SYSTEMS - (septic systems)	LANDFILLS AND OTHER EXCAVATIONS - landfills for industrial wastes, sanitary landfills for municipal solid wastes, landfills for municipal water and waste water treatment plant sludges, other excavations (e.g., mass burial of livestock)	STOCKPILES - highway deicing salt stockpiles, ore stockpiles	RIVER INFILTRATION
WASTE DISPOSAL WELLS AND BRINE INJECTION WELLS		APPLICATION OF HIGHWAY DEICING SALTS	IMPROPERLY CONSTRUCTED OR ABANDONED WELLS
DRAINAGE WELLS AND SUMPS		PRODUCT STORAGE PONDS	FARMING PRACTICES - (e.g., dry land farming)
RECHARGE WELLS	ANIMAL FEEDLOTS	AGRICULTURAL ACTIVITIES - fertilizers and pesticides, irrigation return flows	
	LEAKY SANITARY SEWER LINES	ACCIDENTAL SPILLS	
	ACID MINE DRAINAGE		
	MINE SPOIL PILES AND TAILINGS		

APPENDIX A – ESTIMATED NUMBER OF FACILITIES, VOLUMES OF WASTE, AND LEAKAGE TO GROUND WATER.

Waste disposal practice	Estimated total number	Estimated total size	Estimated amount of waste	Estimated leakage to ground
Industrial impoundments				
Treatment lagoons	NA	NA	1,700 bgy	100 bgy
All impoundments	50,000	NA	NA	NA
Land disposal of solid wastes				
Municipal	18,500	500,000 acres	135 mty	90 bgy
Industrial	NA	NA	NA	NA
Septic tanks and cesspools				
Domestic	16,600,000	-	800 bgy	800 bgy
Industrial	25,000	-	NA	NA
Municipal waste water				
Sewer systems	12,000	470,000 mi	5,000 bgy	250 bgy
Treatment lagoons	10,000	20,000 acres	300 bgy	18 bgy
Land spreading of sludge				
Municipal	NA	NA	NA	NA
Manufacturing	NA	NA	NA	NA
Petroleum exploration and development				
Wells	60,000	-	260 bgy	260 bgy*
Pits	NA	NA	43 bgy	43 bgy
Mine waste				
Coal				
Waste water	277	-	77 bgy	8 bgy
Solid waste	NA	173,000 acres	100 mty	600 m lbs/y acid
Other	691	-	860 bgy	100 bgy
Disposal and injection wells				
Agricultural, urban run-off, cooling water and sewage disposal wells	40,000	-	NA	NA
Industrial and municipal injection wells	< 400	-	NA	NA
Animal feeding operations				
Cattle	140,000	50,000 acres	83 mty	NA
Other	NA	NA	7 mty	NA

bgy - billion gallons per year
mty - million tons per year
m lbs/y - million pounds per year

\- - not applicable
* - almost all returned to salt-water aquifers
NA - insufficient data for estimate

APPENDIX A(continued) - ESTIMATED NUMBER OF FACILITIES, VOLUMES OF WASTE, AND LEAKAGE TO GROUND WATER.

EXPLANATION

INDUSTRIAL IMPOUNDMENTS

Within this category, available data make necessary the separation of secondary treatment lagoons from other impoundments such as settling ponds, pits and basins. The total number of all impoundments in the United States is estimated at 50,000. The flow to these impoundments is not known. The total flow to treatment lagoons alone is calculated at 1,700 billion gallons per year. Average leakage to ground from treatment lagoons is estimated at 6 percent. Thus, the total leakage of industrial waste water from secondary lagoons is estimated at 100 billion gallons per year.

LAND DISPOSAL OF SOLID WASTES

Municipal

An estimated 18,500 municipal solid waste land disposal sites in the U.S. cover a total area of approximately 500,000 acres (estimate based on 25 acres per site). Approximately 135 million tons of refuse per year is landfilled. The volume of leachate generated can be estimated based on average infiltration of precipitation in water surplus areas and on site size. It is estimated that 70 percent of the land disposal sites in the U.S. are in water surplus areas and that the average infiltration is 10 inches per year. Thus, municipal sites would generate a total of 90 billion gallons of leachate per year, most of which goes into the ground.

Industrial

The number of and typical size of industrial solid waste land disposal sites are unknown. A large portion of industrial solid waste, including that which is considered hazardous, presently goes to municipal solid waste land disposal sites.

SEPTIC TANKS AND CESSPOOLS

Domestic

There were an estimated 16,600,000 septic tanks and cesspools in the U.S. in 1970. Annual flow to a septic tank or cesspool from an average house is 49,275 gallons (45 gpd/person x 3 persons/house x 365 days/year). Thus, the total flow to septic tanks and cesspools in the U.S. is about 800 billion gallons per year, virtually all of which enters the ground.

Industrial

It is estimated that about 25,000 industrial septic tanks are currently in use, based on the number of industrial establishments in the U.S. using water. However, little information is available regarding flow rates to these systems and no estimate can be made as to total leakage to ground.

APPENDIX A (continued) - ESTIMATED NUMBER OF FACILITIES, VOLUMES OF WASTE, AND LEAKAGE TO GROUND WATER.

MUNICIPAL WASTE WATER

Sewer Systems

There are currently about 12,000 sewer systems in the United States using approximately 470,000 miles of pipe. Approximately 144 million persons were served by sewer facilities in 1970. Based on an estimated 100 gpd/person sewerage flow (including infiltration-inflow, combined sewer flow, illegal drain hook-ups and industrial waste flow to sanitary sewer lines), the total sewerage flow in sanitary sewers is estimated at 5,000 billion gallons per year. Based on available information, sewer leakage on the average is probably around 5 percent of the total, with wide variations from system to system. Thus, the total leakage for all sewer lines in the U.S. is estimated at 250 billion gallons per year.

Treatment Lagoons

There are approximately 5,000 municipal treatment plants in the U.S. which use lagoons as a treatment procedure. Assuming each plant has an average of two lagoons, there would be about 10,000 municipal treatment lagoons. Assuming each lagoon is roughly two acres in size, there would be about 20,000 acres of municipal lagoons in the country.

Municipal treatment plants using treatment lagoons receive an inflow of approximately 300 billion gallons per year. Leakage from these lagoons is estimated at 6 percent. Thus, it is estimated that municipal lagoons leak 18 billion gallons per year into the ground.

LAND SPREADING OF SLUDGE

Municipal

The number and average size of sludge spreading operations for municipalities is not known. It has been calculated that about 4 million dry tons of municipal sludge is generated each year. How much of this quantity is land spread and how much goes to solid waste land disposal sites and lagoons are unknown.

Industrial

The manufacturing sludge category includes effluent treatment sludge, stack scrubber residue, fly and bottom ash, slag and numerous other manufacturing residues. The total number of industrial sludge spreading sites and typical sizes are unknown. Most industrial sludge presently goes to solid waste land disposal sites and lagoons.

APPENDIX A (continued) - ESTIMATED NUMBER OF FACILITIES, VOLUMES OF WASTE, AND LEAKAGE TO GROUND WATER.

PETROLEUM EXPLORATION AND DEVELOPMENT

Disposal Wells

An estimated 60,000 brine injection wells are in use in the U.S. The total estimated brine disposal is 260 billion gallons per year. Almost all goes into salt water aquifers. The volume which finds its way into fresh aquifers is unknown.

Pits and Basins

An estimated 43 billion gallons per year of oil field brine is disposed of into pits and basins, most of which enters the ground; usually a fresh water aquifer.

MINE WASTE

Coal

Waste Water -

The volume of waste water discharged by the 277 coal mining establishments reporting water consumption in 1972, including processing water and collected mine drainage, totalled 77 billion gallons. The volume of this waste water which entered the ground is not known, but based on the typical geology of the major coal mining regions and what is known about disposal practices, it is estimated at roughly 10 percent, or 8 billion gallons.

Solid Waste -

Between 1930 and 1971, almost 200,000 acres have been used for the disposal of coal mining wastes. Of this area, only 27,000 have been reclaimed. A study in Illinois found that each acre of unreclaimed coal waste could generate 198 lb of acidity (as $CaCO_3$) per day. Assuming half the total acreage of refuse was still producing acid, about 3.6 million tons of acid would be generated each year. On comparison of the location of coal waste dumps with ground-water aquifer types, it is estimated that approximately 10 percent of this total, 600 million lbs of acid/year, might enter the ground-water system.

Other

There were about 1,300 active mines (excluding coal, clay, sand, and stone mines) in the U.S. in 1972. The total solid waste from these mines include some 1.5 billion tons of waste rock plus a large volume of other waste materials from various processing procedures. Of the total number of mines, 691 reported substantial water use in 1972. Total waste water discharged was about 860 billion gallons for that year. A rough estimate of the portion of this volume which would have entered aquifer systems is 10 percent or about 100 billion gallons.

APPENDIX A (continued) - ESTIMATED NUMBER OF FACILITIES, VOLUMES OF WASTE, AND LEAKAGE TO GROUND WATER.

DISPOSAL AND INJECTION WELLS

An estimated 40,000 agricultural, urban runoff and sewage disposal wells are in current use in the U.S. The volume of waste water injected into the ground cannot be estimated. In addition, there are less than 300 industrial injection wells currently in use. The volume of waste injected through these wells is not known.

ANIMAL FEEDING OPERATIONS

Cattle

There are currently about 140,000 cattle feeding operations covering some 50,000 acres in the United States. The total waste deposited in these feeding operations was estimated at 83 million tons in 1975. There are insufficient data in the literature to allow a reasonable estimate of the volume of contaminated runoff from these feedlots which enters the ground.

Other

Very little data are available on the effects of other types of feeding operations, such as sheep, hogs and chickens, on ground-water quality. It is estimated that the total volume of waste from these three sources is 7 million tons per year.

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This document summarizes the report, "Waste Disposal Practices & Their Effects on Ground Water". All material presented in the Executive Summary is duplicated in the full Report so that it will stand alone as a complete document.

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